

Magnetohydrodynamics: Investigations of External MHD Slipstream Accelerator Technologies

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Electric propulsion systems, like the external MHD slipstream accelerators, have excellent prospects for greatly improving the specific impulse of advanced rocket-based combined-cycle engines designed for high-performance, reusable launch vehicles (RLV's) for Earth-to-orbit applications of the future. These MHD thrust augmentation systems will require high-performance rocket-driven MHD generators, as well as special electromagnetic slipstream ionization systems that can enhance the electrical conductivity of slipstream air at the lower hypersonic flight Mach numbers; beyond Mach 18, naturally occurring conductivities may suffice.

Current solid chemical-fueled rocket-driven MHD generators have a propellant utilization efficiency of 0.5 KJ/Kg, whereas 2.0 KJ/Kg may be feasible with advanced liquid fuels. In contrast, utilization efficiencies of laser-heated hydrogen-fueled, rocket-driven MHD generators promise to be several orders of magnitude higher (e.g., 300 to 800 KJ/Kg), which could elevate specific impulses for such advanced beam-boosted RLV engines into the range of 6,000 to 16,000 sec—i.e., truly revolutionary advances.

To pursue this cutting-edge research, it is necessary to understand the physics of the

complicated hypersonic flow phenomena created within MHD slipstream accelerators and air ionization systems. Since there is practically no data available in the open literature on this technology, it is proposed to conduct a combined experimental, theoretical, and computational investigation of the hypersonic flow for such MHD thrust augmentation systems. A CFD algorithm to model this flow will be necessary for simulating the MHD slipstream accelerator (and air spike) performance along a transatmospheric trajectory to orbiting velocity (i.e., Mach 25).

The proposed research program will be carried out at Rensselaer Polytechnic Institute in Troy, NY, and will involve hypersonic testing of two different MHD slipstream accelerator models (one perhaps incorporating an air spike, an air ionization device).

Five major goals for this research project include:

- To demonstrate the ability to control slipstream electrical conductivity;
- To prove that external MHD thrust production is possible;

- To determine the necessary levels of applied magnetic field and plasma current density for efficient MHD acceleration;
- To annihilate the bow shock wave with external MHD forces, and confirm this accomplishment with Schlieren photos; and
- To measure pressures (and perhaps heat transfer rates) across the powered and unpowered hypersonic models (i.e., with, and without the MHD accelerator operating).

Both slipstream accelerator experiments will utilize Rensselaer's Mach 25-class hypersonic shock tunnel (2-ft diameter test section) at Mach numbers of 8.5 to 25 and stagnation temperatures up to 4,100 K.

Sponsor: Advanced Space Transportation Program

University Involvement: Principal Investigator: Leik N. Myrabo, Ph.D., Associate Professor of Engineering Physics, Rensselaer Polytechnic Institute; Troy, NY. Co-Investigator: Professor Henry T. Nagamatsu, Ph.D., Active Professor Emeritus, Rensselaer Polytechnic Institute; Troy, NY.

Biographical sketch: Tony Robertson, of the Component Development Division in the Propulsion Laboratory, has been serving as an advanced propulsion engineer and technical manager in several areas of advanced propulsion since 1995, including magnetohydrodynamics and magnetic levitation. Robertson provides support to Program Development and the Advanced Space Transportation Program in these and other advance propulsion areas. Robertson earned a B.S. in physics and mathematics from the University of North Alabama in Florence, AL, 1982, and earned a master's in operations research from the University of Alabama in Huntsville, AL, 1993. He will soon complete a second master's in engineering management from the University of Alabama in Huntsville, AL, (mid-1997), and plans to seek a Ph.D. in engineering management. ■

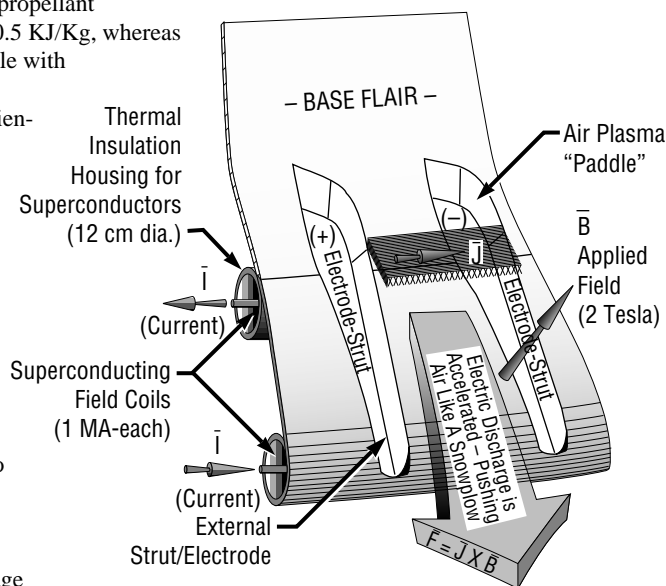


FIGURE 2.—External MHD accelerator.